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An overview of biomass energy utilization in Pakistan

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Abstract

Energy plays a pivotal role in socio-economic development by raising standard of living. Biomass has been used as an energy source for thousands of years by the humankind. Traditional fuels like firewood, dung and crop residues currently contribute a major share in meeting the everyday energy requirements of rural and low-income urban households in Pakistan. An average biomass using household consumes 2325 kg of firewood or 1480 kg of dung or 1160 kg of crop residues per annum. There are good prospects for using biogas energy in rural areas through a network of community biogas plants. Development of fuel-efficient cook stoves is a modest effort to help conserve biomass energy at domestic level. PCRET has so far installed 60,000 energy-conserving, improved cooking stoves all over the country, which are 12–28% efficient. E-10 gasoline pilot project and research on biodiesel production are underway. Sugarcane bagasse can potentially be used to generate 2000 MW of electric power. Attention is now being given to the use of municipal and industrial waste for power generation. The government is financing many projects related to biomass energy development in the country, but still lot more efforts are needed for harnessing full potential and taking maximum benefit out of this important renewable energy resource.

Keywords: Energy; Biomass; Biogas; Bagasse; Pakistan

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1. Introduction

1.1. Energy and biomass

Energy is an integral part of society and plays a pivotal role in its socio-economic development by raising the standard of living and the quality of life. The state of economic development of any region can be assessed from the pattern and consumption quality of its energy. Energy demand increases as the economy grows bringing along a change in the consumption pattern, which in turn varies with the source and availability of its energy, conversion loss and end use efficiency [1].

Through the different stages of development, humankind has experimented with various sources of energy ranging from wood, coal, oil and petroleum to nuclear power. In recent years, public and political sensitivities to environmental issues and energy security have led to the promotion of renewable energy resources. Biomass is one such resource that could play a substantial role in a more diverse and sustainable energy mix. The energy obtained from biomass is a form of renewable energy and, in principle, utilizing this energy does not add carbon dioxide, a major greenhouse gas, to the atmosphere, in contrast to fossil fuels. Defining precisely, the organic matter derived from biological organisms (plants and animals) is called biomass. Biomass has been used as an energy source for thousands of years, ever since humans started burning wood to cook food or to keep warm. As per an estimate, globally photosynthesis produces 220 billion dry tonnes of biomass each year with 1% conversion efficiency [1–3].

1.2. Biomass categorization

Biomass can be categorized broadly as woody, non-woody and animal wastes. Woody biomass comprises forests, agro-industrial plantations, bush trees, urban trees and farm trees. Woody biomass is generally a high-valued commodity and has diverse uses such as

timber, raw material for pulp and paper, pencil and matchstick industries and cooking fuel. Non-woody biomass comprises crop residues like straw, leaves and plant stems, processing residues like saw dust, bagasse, nutshells and husks and domestic wastes (food, rubbish and sewage). Animal waste constitutes the waste from animal husbandry [1].

1.3. Using biomass for energy

The main processes by which energy may be obtained from biomass include direct combustion, pyrolysis, gasification, hydrogasification, liquefaction, anerobic digestion, alcoholic fermentation and transesterification. Each technology has its own advantages, depending on the biomass source and the form of energy needed [3].

Electricity generation is considered the most suitable way for commercial exploitation of biomass, by virtue of the high value of electricity. Biomass based electricity schemes already provide over 9 GWe of worldwide generation capacity. Cogeneration technology, based on multiple and sequential use of a fuel for generation of steam and power, is a viable option for power generation in process industries such as sugar, paper and rice mills, among others. Sugarcane bagasse and sugarcane trash can provide a significant amount of biomass for electricity production, and the potential becomes much higher with advanced cogeneration technologies [2,4,5].

The energy supply from municipal and animal wastes has multiple advantages in that it not only eliminates the environmental pollution but also saves on fuel cost in the manufacturing/processing industries. Energy production from food wastes or food-processing wastes, especially from waste edible oils, seems to be attractive based on bioresource sustainability, environmental protection and economic consideration. Biodiesel, produced from new and used vegetable oils and animal fats, is attractive for several reasons. It is a natural, renewable resource and a cleaner-burning diesel replacement fuel. Just like petroleum diesel, biodiesel operates in compression–ignition engines or diesel engines. Biodiesel has physical properties very similar to conventional diesel. Biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and biodegradability. Depending upon the climate and soil conditions, different countries are looking for different types of vegetable oils as substitutes for diesel fuels. For example, soybean oil in the US, rapeseed and sunflower oils in Europe, palm oil in Southeast Asia (mainly Malaysia and Indonesia) and coconut oil in the Philippines are being considered. Besides, some species of plants yielding non-edible oils, e.g. jatropha and pongamia, may play a significant role in providing resources [6–9].

Animal dung is a potentially large biomass resource and dried dung has the same energy content as wood. When burned for heat, the efficiency is only about 10%. About 150 million tonnes (dry) of cow dung are used as fuel each year across the globe. The efficiency of conversion of animal residues could be raised to 60% by producing biogas through anerobic digestion. Biogas systems offer multiple benefits. For cooking and other household thermal tasks, it is simple and reasonably efficient to use the gas directly in conventional low-pressure gas burners. Biogas can provide lighting when used in mantle lamps. The digester effluent adds economic value by providing valuable fertilizer. It leads to environmental protection as well as improving sanitary conditions in rural areas. Biogas plants are widely in operation in China, India, Sudan, Taiwan, etc. [1,5,6,10].

Plant material particularly rich in starches and sugars such as sugarcane, wheat, etc., can be fermented to produce ethanol. Alternatively, methanol can be produced by the

distillation of biomass, which contains considerable cellulose such as wood and bagasse (residue from sugarcane). Both of these alcohols can be used to fuel vehicles and machinery, and can be mixed with gasoline to make a gasoline/alcohol blend. Brazil's National Fuel Alcohol Program was launched in 1975, based on an initial strategy of substituting gasoline in the internal combustion engines of light vehicles, mainly Otto cycle. Phased in through blends initially at small percentages, it has now reached 24%, with no need for any technical modifications to vehicles [11,12].

2. Biomass energy utilization in Pakistan

Traditional fuels like firewood, dung and crop residues currently contribute a major share in meeting the everyday energy requirements of rural and low-income urban households in Pakistan. Still 67% population is living in rural areas. As a result, this component is much higher in rural areas with dominant use of firewood for cooking and heating purposes. When scarce, firewood is substituted by crop residues and animal dung [13].

Time series data on non-marketed or self-consumed biomass fuels is practically non-existent. However, the 1991–1993 Household Energy Strategy Study (HESS) estimated that by 1992, biomass fuels were providing energy equivalent to 19,256 TOE, which was equal to about 27% of Pakistan's total energy supply. Firewood provided an estimated 60% of this supply, followed by crop residues (21%), dung (18%) and charcoal ($<1\%$) [14].

US Energy Information Administration [15] observes that Pakistan is still shifting to modern energy sources, with firewood, dung and bagasse constituting one-third of all energy consumed in Pakistan as recently as 1988.

World Energy Council [16] reports that wood and other biomass supplied about 47% of the national energy consumption in 1993–1994. Share of biomass in all renewable energy supplies was 83%. The consumption of wood and other biomass fuels was still increasing in absolute terms, even when their percent share in national energy consumption was decreasing. As per WEC Survey of Energy Resources 2001 [17], Pakistan has a very small proportion of its total land area under forest—only some 25,000 km^2, or 3.2% of the total. In 1998, 39% of its inland primary energy supply was furnished by biomass fuels, of which more than one-third consisted of fuelwood. FAO estimates point to a 1999 level of fuelwood production of around 24 million tonnes.

According to UNDP estimates, 23.5% of total energy requirements of Pakistan were met by traditional fuels in 2003. The corresponding figure for 1997 is given as 29.5% [18].

It is estimated that an average biomass using household consumes 2325 kg of firewood or 1480 kg of dung or 1160 kg of crop residues per annum. The HESS assessed that the total standing wood stock was about 210 million tonnes, with an annual sustainable production of 22.7 million tonnes. Similarly, 12–15 million tonnes of crop residues (principally cotton sticks) were available each year [19].

2.1. Biogas

There are good prospects for using biogas energy in rural areas of Pakistan through a network of community biogas plants. The amount of dung-waste is enough to produce about 12 million cubic meters of biogas per day that could suffice to meet energy requirement of 28 million rural people, in addition to production of 21 million tonnes of bio-fertilizer per year. Directorate General of New and Renewable Resources (DGNRER)

under the Ministry of Petroleum and Natural Resources started a comprehensive biogas scheme in 1974 and until 1987 commissioned 4137 biogas units throughout the country. The units were designed to provide 3000 and 5000 cubic feet of biogas per day for cooking and lighting purposes [14].

The program was developed in three phases. In Phase I, DGNRER installed 100 demonstration units of Chinese fixed-doom design on grant-basis. During Phase II, the cost of the biogas plant was shared between the beneficiaries and the government and in Phase III, government withdrew the financial support; however, free of cost technical support remained but not on persistent basis. This program practically failed due to the following reasons [14]:

- Withdrawal of government financial support
- Lack of technical training to the communities
- Lack of awareness raising and experience sharing
- High cost of the technology
- Lack of motivation and incentives
- Inadequate demonstration
- Inadequate communities' (beneficiaries') participation

Parallel to DGNRER, the Pakistan Council of Appropriate Technology (PCAT) was also working for the development of renewable energy technologies under the Ministry of Science and Technology, which was curtailed to R&D for the promotion of biogas technology in the country and became focal point for the biogas-related activities. In 2001, PCAT was merged with National Institute of Silicon Technology to create Pakistan Council of Renewable Energy Technologies (PCRET) under the same ministry. PCRET has initiated a comprehensive package for the development and dissemination of biogas plants and other appropriate sustainable technologies into the lives of the people in rural areas of the country [14].

Recently, PCRET has installed 1200 biogas plants throughout Pakistan on cost-sharing basis, where 50% cost is to be borne by the beneficiary [20]. Apart from these, three community size biogas plants have been installed in rural areas of Islamabad, which are meeting domestic fuel needs of 20 houses. A 1000 m^3 biogas plant is being designed for installation near Cattle Colony, Karachi [20].

The biogas plants constructed in Jabbi Niazi and Korak (Fatehjang), with 50% community contribution, are working efficiently. The two households have found that the gas generated is enough to meet their domestic cooking requirements. The efficiency of effluents from the plants, which is reported to be a better natural fertilizer than the one prepared by traditional methods, will be tested in fields. Many more biogas plants in Rural Support Programme's project areas are being constructed with the collaboration of PCRET [10].

It is reported that presently there are 5357 biogas units installed in the country. The unit sizes are 3–15 m^3/day. The estimated countrywide biogas potential is 12–16 million m^3/day [21].

2.2. Fuel-efficient stoves

Wood, crop residues, dung and grass are used in about 60% of the households in the country as energy sources for cooking and heating. Development of fuel-efficient cook

stoves is a modest effort to help conserve biomass energy at domestic level. Improvements in the efficiency of the conventional cook stoves have reduced the consumption of wood, thus mitigating environmental pollution, saving domestic expenditure and slowing down deforestation. Fuel Efficient Cooking Technology project was funded by GTZ of Germany and implemented throughout the country. Following encouraging results, another program (Fuel Saving Technology) was initiated by the government. The program, providing incentives to NGOs and community-based organizations, resulted in NGOs and private sector improving the quality and efficiency of cook stoves to a level that they are now exporting cook stoves to Afghanistan and Central Asian States [10,19].

Fifty molds of fuel-efficient stoves were prepared and provided to the field units of NRSP. The communities were trained for their use. The communities are using the stove molds for constructing fuel-efficient stoves. Some of the females have started it as an enterprise and are selling the stoves [10].

PCRET has so far installed 60,000 energy-conserving, improved cooking stoves all over the country, which are 12–28% efficient [21,22].

2.3. E-10 Gasoline pilot project

Pakistan State Oil has launched E-10 gasoline pilot project at designated retail outlets in Karachi, Lahore and Islamabad. It is based on a detailed feasibility study conducted by the Hydrocarbon Development Institute of Pakistan (HDIP). The new fuel—10% ethanol blended with motor gasoline—is being introduced experimentally as part of government's strategy to promote alternative energy resources. The pilot project is being conducted for 6 months, with 25 pre-identified vehicles using ethanol-blended gasoline in each city. The monitoring of these vehicles will be carried out by HDIP. Based on the results of the project, the blended fuel would be made available throughout the country. Pakistan's sugar industry has a capacity of producing four billion liters of ethanol annually [23–25].

2.4. Biodiesel

The initial research on biodiesel resources in Pakistan is complete. The potential oil resources identified include *Pongamia pinnata*, rapeseed and castor bean [20].

The Alternative Energy Development Board has recently invited tenders for Pilot Project of Production Plant of Biodiesel. AEDB intends to electrify one village through biodiesel-based power generation plant, as part of its National Rural Electrification Program [26].

2.5. Bagasse

There is abundant opportunity for wider use of bagasse-based cogeneration in the world's main cane-producing countries like Brazil, India, Thailand, Pakistan, Mexico, Cuba, Colombia and the Philippines. The world's major cane producers (excluding China) collectively produce 70% of global cane, and bagasse cogeneration could account for an average of 7% demand of the eight countries [27].

Pakistan is the fifth largest sugarcane producer in the world with a production of 47,244,100 million tonnes [28]. The government has allowed Pakistan Sugar Mills Association to cogenerate 2000 MW electric power by using bagasse as fuel [29].

2.6. Urban and industrial wastes

In Pakistan, big cities produce millions of tonnes of household, cattle, poultry and industrial wastes each year that have created health and other environmental hazards on significantly larger scale. Public and private sectors are well aware of its disposal crisis but know little about its potential utilization for electric power generation to lessen the present power shortages in the country. Baseline works are not enough to implement any major projects. Lack of adequate awareness about the management of different types of wastes and related technologies for the generation of energy from these wastes is one of the main barriers to promote such renewable energy resource in Pakistan [14].

3. Plans and strategies to promote biomass use in Pakistan

The targets set in National Development Vision—2004 and PCRET Vision—2020 are as follows [21]:

- Provision of 250 m^3/day biogas plants for 50,000 families
- Generation of 500 MW electric power using municipal/agriculture solid waste

Three projects with a total budget of Rs. 37.77 million were approved by the government for implementation during 2002–2005 period. They covered the areas of fuel saving technology, promotion of biogas and dissemination of biogas plants for meeting energy requirements.

Various measures are prescribed for the promotion of biomass energy in the country. The prominent ones include R&D in conversion technologies, provision of better institutional infrastructure, dissemination programs to promote efficient usage and appropriately defining role of biomass in the overall energy and environment policy. There is enormous potential for growing dedicated energy crops on agricultural lands ravaged by problems of waterlogging and salinity. The other wastelands can be used for the same purpose as well. Private sector participation in such endeavors should be encouraged. The biomass output thus obtained can be used for centralized power generation.

4. Conclusion

Biomass, as a clean and cost-effective fuel option, has tremendous potential for application in Pakistan. Necessary know-how about most of the biomass energy technologies already exists. There is just a need to allocate necessary resources for improving these technologies and plan their widespread dissemination. Better coordination between existing institutions is required to avoid duplication of research.

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